Assimilation of high-frequency radar data in the east Chukchi Sea

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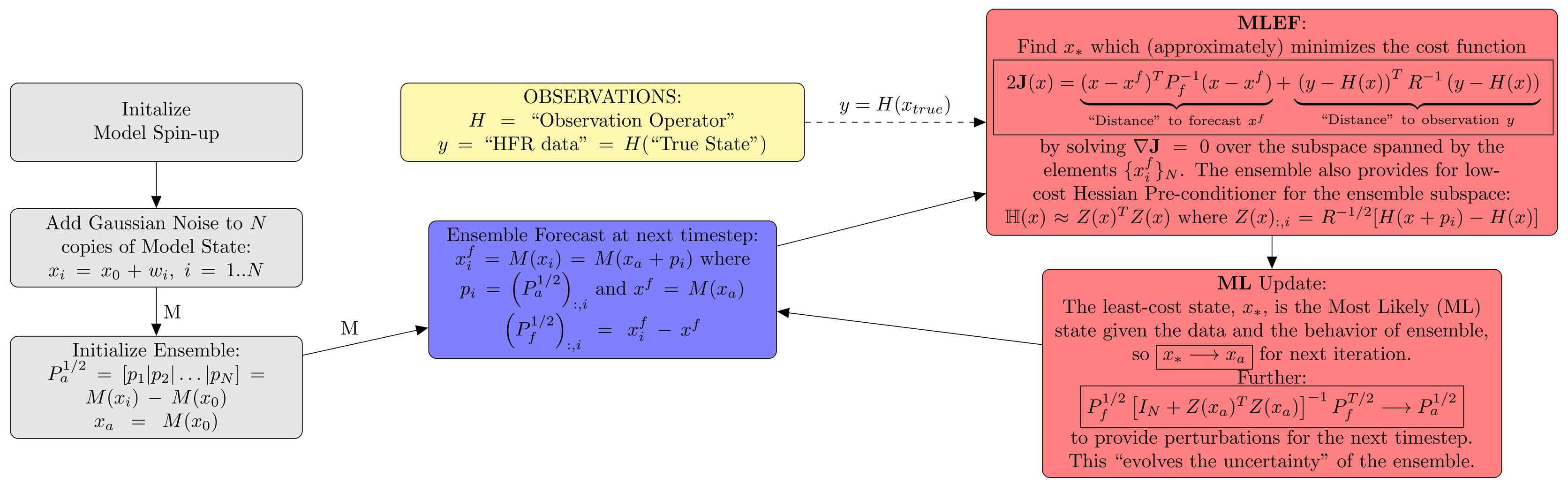
The maximum-likelihood ensemble filter (MLEF) is an efficient technique of data assimilation related to both 3D-variational (3Dvar) and Ensemble Kalman Filter (EnKF) methods[5]. We demonstrate the utility of MLEF by assimilating high-frequency radar (HFR) data into a realistic model of the east Chukchi Sea. A set of three radar stations in Wainwright, Point Lay, and Barrow provide two-dimensional resolution of the sea-surface velocity. We use MLEF to incorporate this HFR data into a numerical model constructed using the Regional Ocean Modelling System (ROMS) for the ice-free months of 2012. The resulting analysis can be used as a benchmark for future operational forecasting, allowing for better real-time monitoring and decision-making as this biologically-rich region is influenced by industry and commerce.

Objective

Assimilate data from coastal HFRs at Barrow, Wainwright, and Point Lay into a regional ROMS model of the east Chukchi sea.

DA Algorithm



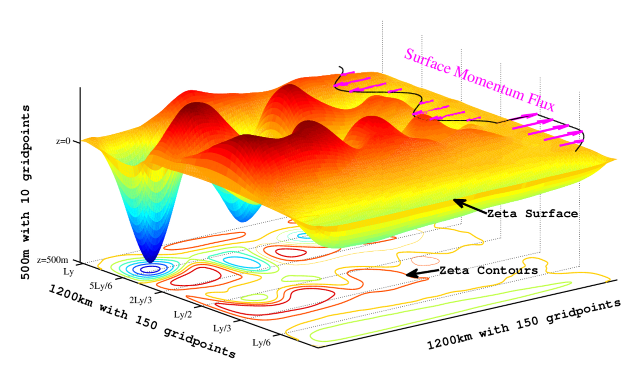
⇑ Schematic outline of MLEF data assimilation

At each analysis step (red), find the most likely model state, given data (yellow) and forecast (blue), within the span of the ensemble

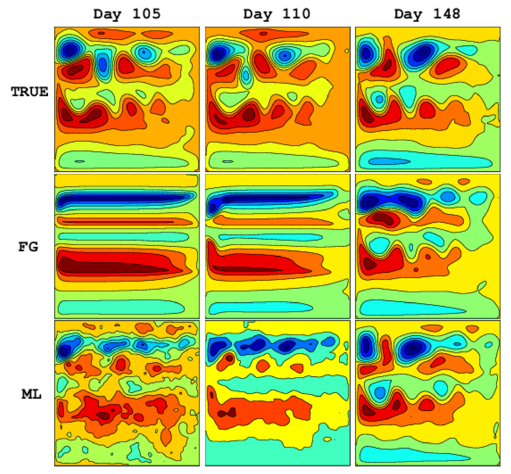
- Cheap low-dimensional optimization, easy ensemble parallelization
- H may be nonlinear, even discontinuous observation operator
- Need not assume Gaussian distribution of variables (but we do for now)
- Unlike eg. nudging, accounts for relative uncertainties in model and data

Previous testing with ROMS:

We modeled a **1200km×1200km×500m** closed test domain with **Lx×Ly×Lz=150×150×10** gridpoints subject to surface forcing, huge coriolis term, and low viscosity, then applied MLEF using data sampled from every α^{th} gridpoint.

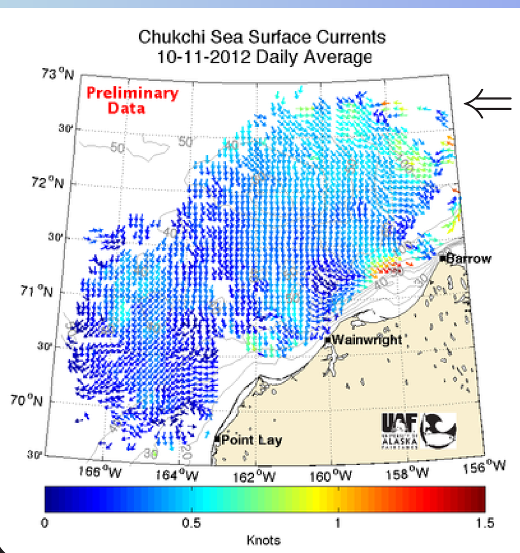


DA start@ day 100
daily assimilation
$\alpha = 2$
FG=first-guess
ML=MLEF analysis



The DA algorithm properly assimilated u,v,&SSH (plotted) data. ⇑

HFR Data

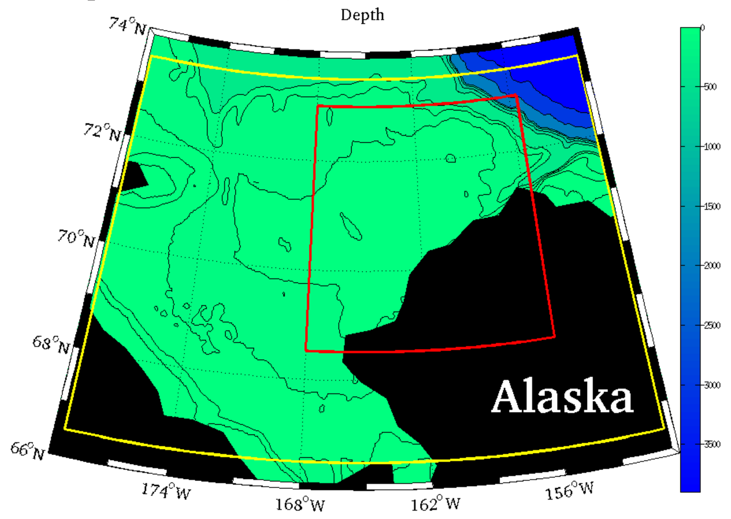


⇐ Example HFR-measured surface velocities [4].
(Image: `http://www.ims.uaf.edu/hfradar/`)

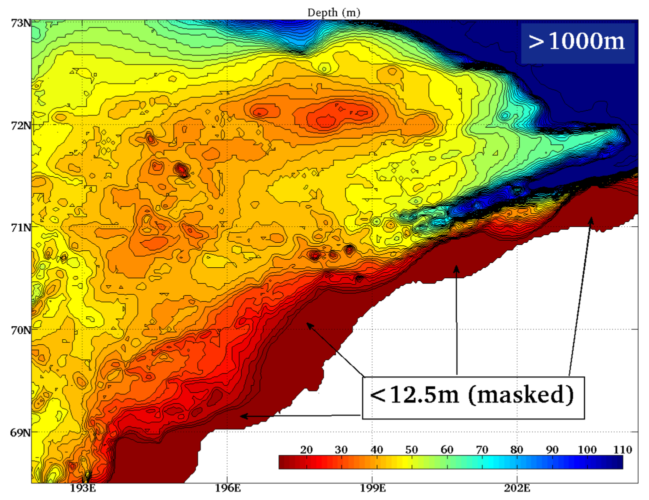
- Need overlap of 1D data for 2D resolution.
- Uncertainty depends on distance from antenna, angles of ray intersection, and apparatus precision [2].
- Point-wise data represents 5° × 6km cell, but we interpolated to computational grid
- High-density but intermittent and "gappy"

Model Domain

Using ROMS, we model the east Chukchi region [192.0,204.45]E x [68.525,73]N at ∼2km resolution ⇓



- Grid: **Lx×Ly×Lz=250×180×20** gridcells
- State: Velocities (u,v) and SSH [barotopic]
- Temperature, but constant salt/density
- 2012 Spin-up 01Jan to 01Aug (214 days)
  - Ensemble of 32 models started day 210
- Open-boundaries and realistically forced



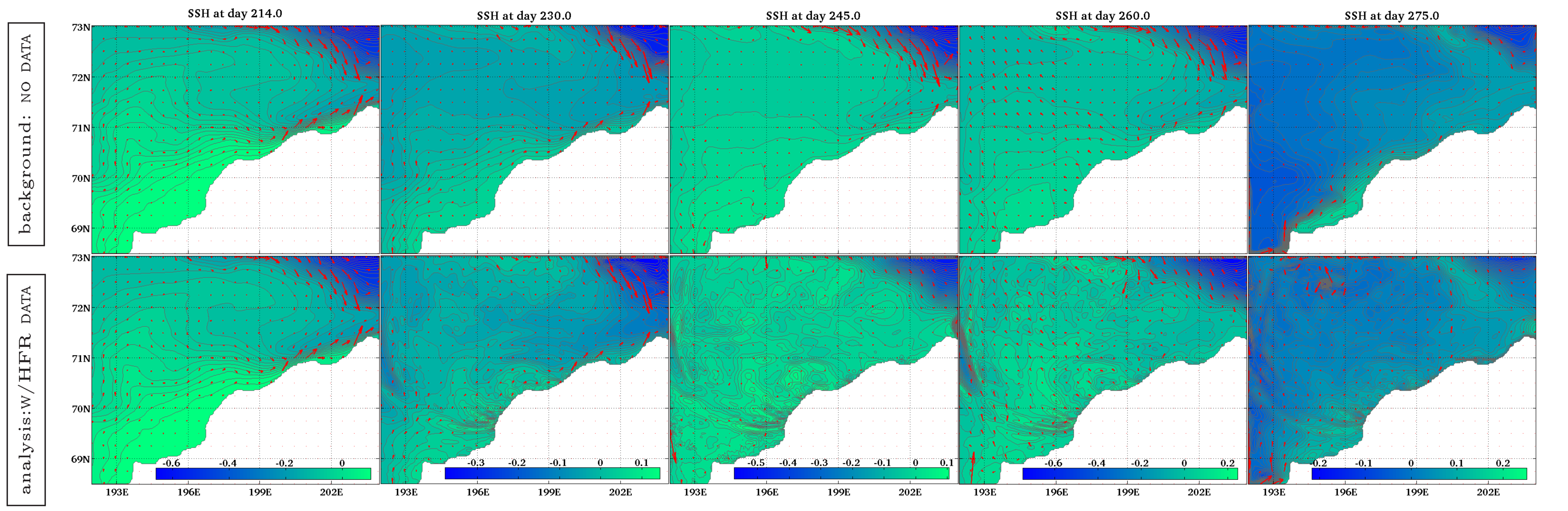
Forcing: Winds and other atmospheric forcing by 6-hourly NCEP Reanalysis data (provided byNOAA/OAR/ESRL PSD from their website at http://www.esrl.noaa.gov/psd/).

Boundary data: Oceanic boundary conditions for the domain were interpolated from daily ECCO2 Cube92 model output (provided by NASA through the website at http://ecco2.jpl.nasa.gov/products/) and run *a priori* on coarse domain (yellow square, at ∼12km resolution) to supply boundary conditions to 2km domain box.

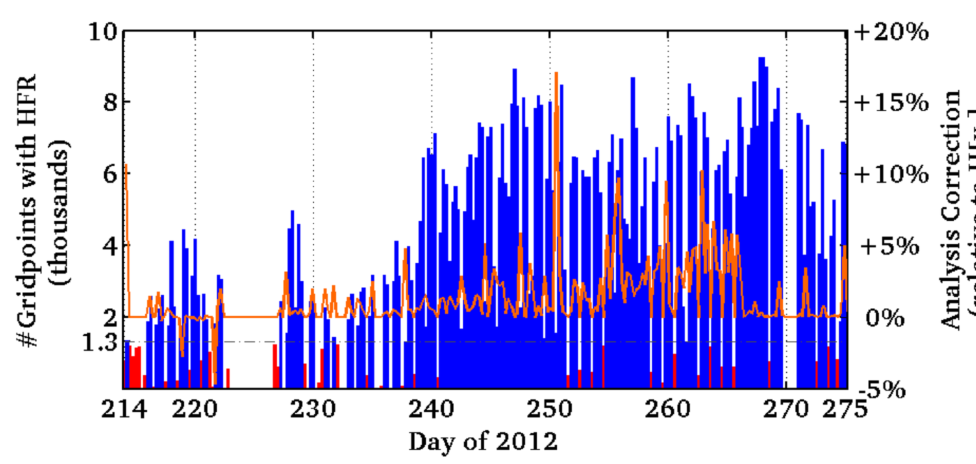
Future: Downscaling of forcing and flux data via Weather Research & Foreast (WRF) model for 2km domain.

DA application

An ensemble of $N = 32$ realizations ran from day 210 (July28) to day 275 (Oct.1), incorporating synoptic HFR data every 6 hours starting at day 214 (Aug 1). The error covariance matrix R for the HFR data was taken to be diagonal (independent) with uncertainty artificially set to a mimimum of 0.2m/s at the surface near the coast, rising linearly with distance from nearest HFR station and held constant to a depth of 2.5m. Assimilation of HFR surface velocity data is sufficient to change free surface:



SSH contours (in m) are equal in each column; red arrows show surface velocity direction and relative magnitude.



⇐ Time series of data-volume and innovation norm. Height of blue boxes reflects the number of domain gridpoints with HFR data. Red boxes (below 1300 gridpoints) represent the smallest ∼5% of total data and were not assimilated. The orange curve shows the norm of the innovation due to assimilation, relative to the error between forecast and observation.

Conclusions

This early work shows that MLEF is able to assimilate HFR data, which may be sparse and intermittent at times and rich at others, into an open-boundary high-resolution ROMS domain for the barotropic case. Such results are useful to resolve small-scale eddies and waves.

Ongoing

- Hourly assimilation windows
- Downscaled atmospheric forcing
- Improve boundaries & viscosity
- Accurate uncertainty of HFR (ie. better R)
- Correlation comparison with satellite data
- Log-Normal (non-G) obserations
- Baroclinic case (w/ T,S,ρ)
- 2010-2013 summer (JASO) runs

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